Abstract

A new suboptimal guidance law design approach for aerospace vehicles is proposed in this thesis, followed by an advanced control design for supersonic air-breathing engines. The guidance law is designed using the newly developed generalized model predictive static programming (G-MPSP), which is based on the continuous time nonlinear optimal control framework. The key feature of this technique is one-time backward propagation of a small-dimensional weighting matrix dynamics, which is used to update the entire control history. This key feature, as well as the fact that it leads to a static optimization problem, lead to its computational efficiency. It has also been shown that under the Euler integration and the rectangular approximation of finite integrals, the proposed technique is equivalent to the existing model predictive static programming technique, which is based on the discrete time framework. The G-MPSP technique is further extended to incorporate 'input inequality constraints' in a limited sense using the penalty function philosophy. Next, this technique has been developed also further in a 'flexible final time' framework to converge rapidly to meet very stringent final conditions with limited number of iterations.

Using the G-MPSP technique in a flexible final time and input inequality constrained formulation, a suboptimal guidance law for a solid motor propelled carrier launch vehicle is successfully designed for a hypersonic mission. This guidance law assures very stringent final conditions at the injection point at the end of the guidance phase for successful beginning of the hypersonic vehicle operation. It also ensures that the angle of attack and structural load bounds are not violated throughout the trajectory. A second-order *autopilot has been incorporated in the simulation studies to mimic the effect of the inner-loops on the guidance performance. Simulation studies with perturbations in the thrust-time behaviour, drag coefficient and mass demonstrate that the proposed guidance can meet the stringent requirements of the hypersonic mission. Furthermore, a performance comparison study with the shooting method shows that the proposed G-MPSP is a computational efficiency technique.*

The G-MPSP technique in a fixed final time and input inequality constrained formulation has also been used for optimal guidance of an aerospace vehicle propelled by supersonic air-breathing engine, where the resulting thrust can be manipulated by managing the fuel flow and nozzle area (which is not possible in solid motors). However, operation of supersonic air-breathing engines is quite complex as the thrust produced by the engine is a result of very complex nonlinear combustion dynamics inside the engine. Hence, to generate the desired thrust, accounting for a fairly detailed engine model, a dynamic inversion based nonlinear state feedback control design has been carried out. The objective of this controller is to ensure that the engine dynamically produces the thrust that tracks the commanded value of thrust generated from the guidance loop as closely as possible by regulating the fuel flow rate. Simultaneously, by manipulating throat area of the nozzle, it also manages the shock wave location in the intake for maximum pressure recovery with sufficient margin for robustness. To filter out the sensor and process noises and to estimate the states for making the control design operate based on output feedback, an extended Kalman filter (EKF) based state estimation design has also been carried out and the controller has been made to operate based on estimated states. Moreover, independent control designs have also been carried out for the actuators so that their response can be faster. In addition, this control design becomes more challenging to satisfy the imposed practical constraints like fuel-air ratio and peak combustion temperature limits. Simulation results clearly indicate that the proposed design is quite successful in assuring the desired performance of the air-breathing engine throughout the flight trajectory, i.e. both during the climb and cruise phases.